Structural Integrity of Hydrogen Storage Tanks at Pre-Stressing and Operating Pressures

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Abstract

With the fuel prices reaching record highs and ever-increasing tighter environmental policies, hydrogen-powered vehicles have great potential to substantially increase overall fuel economy, reduce vehicle emissions, and decrease dependence on foreign oil imports. While hydrogen fuel is exciting for automotive industries due to its potentials of significant technical and economic advantages, design and manufacture safe and reliable hydrogen tanks is recognized as the number one priority in hydrogen technology development and deployment. Real life tank performance testing is extremely useful, but very time consuming, expensive, and lacks a rigorous scientific basis, which prohibits the development of a more reliable hydrogen tank. However, very few testing and simulation results can be found in public literature.

This paper focused on the development of an efficient finite element analysis (FEA) tool to provide a more economical alternative for hydrogen tank analysis, though it may not be an all-out replacement for physical testing. A FEA model has been developed for the hydrogen tank with 6061-T6 aluminum liner and carbon-fiber/epoxy shell to investigate the tank integrity at pre-stresses of 45.5 MPa, 70 MPa, and 105 MPa and operating pressures of 35 MPa, 70 MPa, 105 MPa. The residual stresses induced by different pre-stresses are at the equivalent level in the middle section but vary significantly in other tank sections. Residual stress magnitudes may saturate at a certain pre-stress level. In contrast, residual strains in the middle section show significant difference at different pre-stress levels. The simulation results indicate that the optimal pre-stress level depends on the specific operating pressure to enhance tank integrity. A certain area of the neck and the top and bottom domes also experiences peak stress and strain at pre-stressing and regular operating pressures. The research findings may help manufacturing industries to build safety into manufacturing practices of hydrogen storage infrastructures.

Keywords: Hydrogen tanks; FEA; Safety; Crashworthiness; Fuel cell vehicles